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Evaluation of a Soil Compaction as Concerned to Land Use

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Abstract

The main objectives of this paper were (1) to determine soil bulk density of undisturbed samples, using both conventional and computed tomography (C.T.) techniques to identify soil compaction processes and (2) to compare the two methodologies. Soil samples were collected in a semi-arid region of Petrolina, PE, Brazil, along the soil profile, in 0.1 m steps down to 1 m depth, at two sites: 1. Soil under natural vegetation "caatinga", and 2. Cultivated soil irrigated by central pivot. Soil C.T. scanning was performed with a first generation C.T. scanner and the conventional method was the gravimetric method (mass and volume measurement of the sealed clods). Results suggest that there is a natural soil compaction in deeper layers, and for the pivot irrigated area, the presence of man induced compacted layer, between 0 and 0.4 m. The comparison of the methods presented soil bulk density values of satisfactory coincidence.

1. Introduction

The occurrence of natural and man induced soil compaction may directly interfere in soil water and solute dynamics, as well as in root system distribution and soil aeration. Natural compaction is a characteristic of soils that present an increase in the number of smaller particles along profile depth, leading to a textural gradient and density increase downwards (Oliveira et al., 1994). The use of machines in agriculture can cause a man-induced compaction affecting soil water retention and soil water transport.

As these processes can take place in thin layers of soil, conventional methods to determine density may not be sensible enough to a correct evaluation of these processes. C.T. imaging has been shown to be a satisfactory tool to achieve this purpose. (Crestana et al., 1986; Vaz et al., 1989; Naime et al., 1997).
In the Brazilian semi-arid northeast region, irrigation is fundamental to plant development as rain precipitation presents very low magnitude as well as its temporal distribution be very irregular. Thus the land use must be

be adequate to this practice.

The objectives of this paper were (i) to the occurrence of compaction in two areas of the specified region of Petrolina (PE), distinguished by its land use and management and (ii) to use C.T. imaging to determine soil bulk density and to compare it to gravimetric method.

2. Material and Method

Two areas were selected in the Brazilian Northast, located in Petrolina (PE) - latitude 09° 09'S, longitude 40° 22'W, altitude 365 m). These areas were sited side by side but distinguished from each other in terms of vegetation: (1) native vegetation (NVA), called caatinga; (2) vegetation under central pivot irrigation (CPA).

One trench was dug in each area and soil samples were collected from each horizon to determine granulometry and textural class of soil (Embrapa, 1997). The samples to determine soil density were collected undisturbed (0.1 x 0.1 x 0.1 m^3 clods) along soil profile down to 1m depth. These samples were sealed with paraffin to maintain soil structure and water content. Ten samples were collected in each area.

The methods used to determine soil bulk density were the gravimetric method, using paraffin sealed clods (Embrapa, 1997), and the C.T. imaging method (Vaz et al., 1989). The scanner used is a CENA/USP equipment, Piracicaba (SP). Its main parts are: ^{137}Cs (300 mCi) radioactive source; NaI(Tl) detector with photomultiplier; lead collimators, 2 mm internal diameter; 20 cm source-detector distance. Sample positioning is made by a mechanical system that provides linear and rotational movements and the pulses are processed by the system electronics (Figure 1). The scanner calibration was performed through the correlation between the values of the linear attenuation coefficient obtained in direct transmission method and the values from C.T. image of homogeneous samples (Vaz et al., 1989).

The C.T. images were obtained following a vertical plane crossing the central region of the samples. The average values of density (D_s, kg.m^{-3}) were calculated as follows:

$$D_S = TU/K(\mu_S + \mu_w W) \qquad (1)$$

where K is the correlation between the linear attenuation coefficient μ and the tomographic units TU; μ_s and μ_w (m^2.kg^{-1}) respectively are the mass attenuation coefficients of soil and water. W is the water content of samples as it was collected. To measure μ_s and μ_w both soil and water was poured in containers with known geometry and the direct transmission technique was applied. The soil was sieved in 2mm sieves. The gravimetric method was used to determine W (Embrapa, 1997). To determine water content the samples were oven dried during 36 hours at 110 °C.

3. Results

The soil of both areas was classified as a eutrophic plinthic Red Yellow Podzol Tb. Its granulometry and textural class is presented in Table 1. An increment in clay fraction and consequently a change in textural class can be observed from layers 45-60 cm and down in NVA and 27-45 cm and down in CPA. These results suggest the occurrence of natural compaction to both areas because the gradient is very abrupt. In CPA the alterations took place in more superficial layers than in NVA. This probably is due to soil management, which promoted layer inversion.

The results of the C.T. scanner calibration are shown in Table 2 and Figure 2.

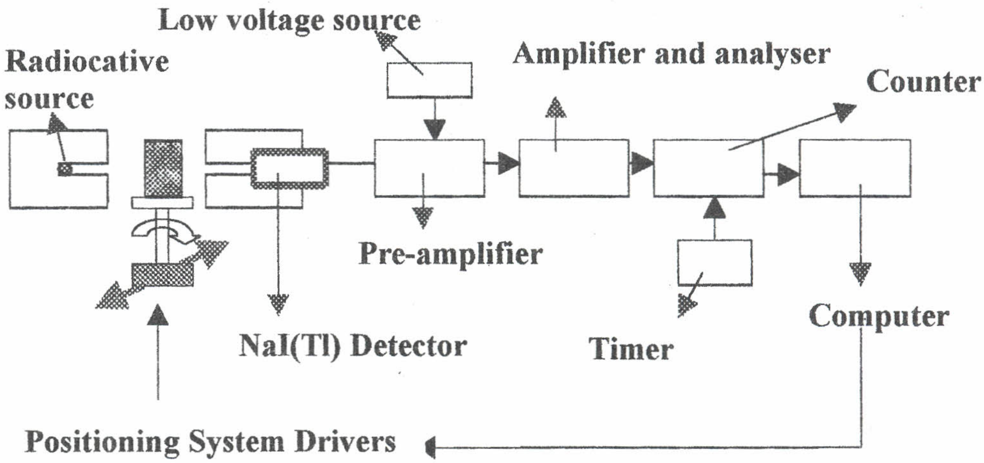


Figure 1 – Schematics of CENA/USP C.T. scanner used in this paper.

Table 1 – Granulometric analysis and textural classification of an eutrophic plinthic Red Yellow Podzol Tb soil in the natural vegetation area (NVA), caatinga, and central pivot area (CPA).

	Layer (cm)	Sand $g.kg^{-1}$	Silt $g.kg^{-1}$	Clay $g.kg^{-1}$	Textural Class
	0-18	860	60	80	Loamy sand
	18-33	860	60	80	Loamy sand
	33-45	820	80	100	Loamy sand
	45-60	660	100	240	Sand clay loam
Area	60-75	520	110	370	Sandy clay
	75-110	510	140	350	Sandy clay
NVA	110-170	540	180	280	Sandy clay
	170-205	490	190	320	Sandy clay
	0-15	840	80	80	Loamy sand
	15-27	850	70	80	Loamy sand
	27-45	720	80	200	Sand clay loam
	45-65	580	140	280	Sand clay loam
	65-110	520	90	390	Sandy clay
	110-160	590	110	300	Sandy clay
CPA	160-200	560	140	300	Sandy clay
	200-230	530	130	340	Sandy clay

It can be noticed in Table 2 that the values of linear attenuation coefficient of the samples used in the C.T. scanner calibration (μ), as well as the average value of the soil mass attenuation coefficient (μ_s = 0.754 m^2kg^{-1}), are in accordance to the literature (Ferraz & Mansell, 1979). A good correlation between μ e TU was achieved (Figure 2), too.

Figure 3 presents the average value of soil density (D_S), and their maximum and minimum values as obtained from the associated standard deviation, for each undisturbed sample, corresponding to the 0.1m soil layers, for each evaluated area using both C.T. imaging and gravimetric methods. In this figure it can be inferred the existence of a compacted layer between 0 to 0.4m, in CPA.

Table 2 – Average values of linear attenuation coefficient (μ) and tomographic units (TU) of homogeneous samples utilized to calibrate the CENA/USP scanner.

Sample	Linear Attenuation Coefficient (μ) x 10 ^{2} (m^{-1})	Tomographic Units (TU)
water	0.0833	86.0
glycerin	0.1012	104.2
alcohol	0.0677	72.5
Brass	0.6050	565.9
Aluminum	0.1973	202.9
Acrylic	0.0987	97.9
Nylon	0.0955	98.5

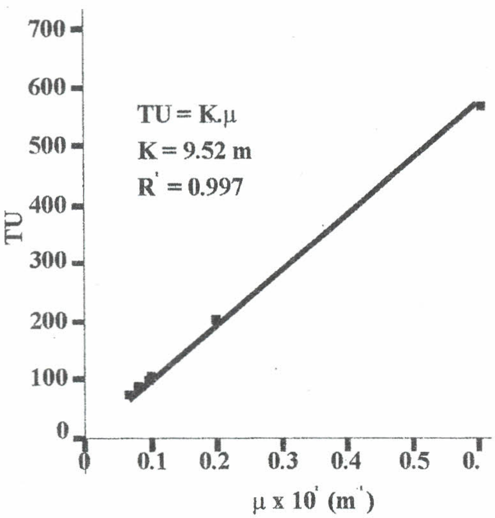


Figure 2 – Linear regression between the linear attenuation coefficient μ and the tomographic units TU of CENA/USP scanner.

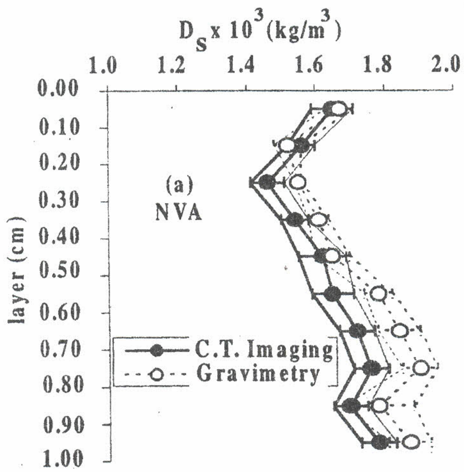
The results to the caatinga area (NVA), by both C.T. scanning and gravimetry, showed an increase in density along soil profile in downward sense and near the textural gradient zone, which can be interpreted as a natural compaction in deeper layers of this soil. On the other hand, this compaction process in irrigated area (CPA) cannot be completely observed from the results. Maybe the surface compaction avoided the formation of the process in deeper layers (Table 1).

Comparing the two methodologies, a satisfactory agreement for the average soil densities can be noticed, mostly for NVA. The greatest differences are observed in deeper layers and in CPA, where the average densities calculated by C.T. imaging were slightly lower than by the gravimetric method.

Figure 4 shows the average density values in 2.5mm layers along depth as calculated by C.T. imaging for both areas. Soil compaction can be observed in this figure for NVA and in a layer in CPA from 0 to 0.4 m. A structure of soil can be inferred from this figure represented by the fluctuation of density.

4. Conclusions

* The occurrence of naturally compacted layers was observed along soil profile, possibly due to clay migration, mostly for caatinga area (NVA);
* In irrigated area (CPA), an artificially compacted layer from 0 to 0.4 m was observed, probably due to management andland use of this area;
* There was a satisfactory agreement between the two methods and C.T. imaging showed a better spatial esolution, allowing a detailed evaluation of density along soil profile depth.



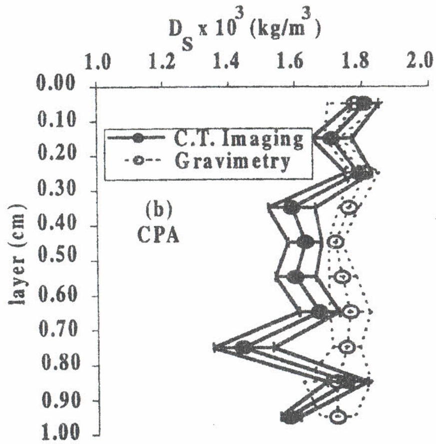


Figure 3 – Average soil density (D_S) and respective standard deviations, determined by C.T. imaging and gravimetric methods in 0.1 m layers: (a) natural vegetation area – caatinga - (NVA); (b) central pivot irrigated area (CPA).

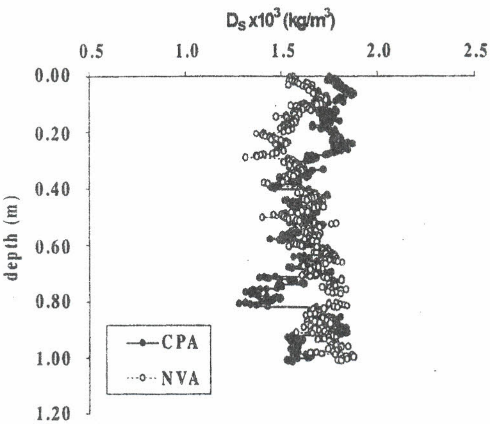


Figure 4 – Average soil density (D_S) determined in 2.5 mm layers by C.T. scanning for the two areas studied (NVA and CPA).

5. Acknowledgment

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